ON

ELECTRIC PHENOMENA.

BY

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The greater the progress, which Natural History makes in the knowledge of facts and their inner coherence, the more easy it is to understand those causes which lay the foundation of the facts. Whilst formerly, as an explanation for almost every phenominal appearance, the existence of its own peculiar substance was admitted (for example "Caloric", which was considered as imponderous, or, still earlier, that so-called "Phlogiston", which is supposed to contain such a negative weight, that through its existence the other bodies which are connected with it, become much lighter); we now attain, more and more, the knowledge, that every phenomenon of Nature is to be traced back to the motions of the smallest particles of which all matter is composed.

The phenomena on which I intend to discourse, are very remote from this notion. However minutely they may have been investigated separately, and whatever great results they may have led to in a practical sense, in order to explain them fully, it is necessary for us to make an assumption ("hypothesis" as it is called by men of science), for the accuracy of which we have no proof, and it is only devised for the purpose of concentrating the whole series of phenomena into a general point of view. The value of such suppositions con-

sists principally in their use as a medium of instruction, and they can be abandoned as soon as they evince themselves as inefficient, or we can find more simple and therefore better ones.

According to the supposition in question, there are two highly subtile, imponderable and elastic fluids, which are so refined, that we are not able to weigh them in the most accurate scales, but infer their existence from their effects. These fluids are called positive and negative electricity. Each has the quality to repel that body, which is impregnated with its own identical fluid, and on the other hand, to attract that which possesses the opposite, and this attraction and repulsion take place in inverse ratio to the quadrat of the distance from one another; i. e., if two electrical fluids are twice or three times as far from one another, then their repulsive or attractive influence is only of one fourth or one ninth of the power it would be, were a simple distance between them.

These two fluids always exist, where solid substance is to be found, they cling to the smallest particles of matter, but nevertheless they are capable of passing from one molecule to the other in one and the same body, as well as from one body to another. Generally these two fluids are present in equal quantities in all bodies, and the result thereof is, that they cannot exercise any sensible influence outwards. We then call the bodies *neutral-electric* or *non-electric*. When, however, in a body one of the fluids is found in a larger quantity than the other, its stronger effect asserts itself and we call the body *electric* and indeed *positive-electric*, if the positive fluid exists in excess, and *negative-electric*, if the negative fluid preponderates.

Among the means, which effect such an unequal distri-

bution of electric fluid, friction takes the first place. If we rub a stick of sealing-wax with a piece of woollen cloth, and then touch with the sealing-wax a light little ball made of the pith of the elder-tree and suspended by a silken-thread, we shall find, that the ball is at first attracted by the sealing-wax, but as soon as it comes in contact with it, it is quickly repelled. It is evident, that this last repulsion can only be caused by the fact, that the stick of sealing-wax has imparted to the ball a small part of that electricity, which has been excited by friction, and that now the state of electricity in the sealing-wax and the little ball being similar, they reciprocally repulse each other. As the ball is very light and hangs quite free, the electric fluid carries with it the material particles to which it adheres, and thus, the repulsion, which takes place between the invisible electric fluids becomes perceptible to us through the movement of the visible substance.

If we now rub a piece of glass and touch with it a second ball hung up in a similar manner, and of the same kind as the before-mentioned, we attain just the same result. The piece of glass becomes electric through friction; it also imparts to the ball through contact a portion of its electricity and the electricity of a similar kind contained in the glass and the ball, repulse one another. If we now bring the piece of glass in contact with the ball, which was first touched with the sealing-wax, it will be attracted by it, and likewise, the ball, which was first touched by the piece of glass, will be attracted by the sealing-wax. We conclude therefrom, that the electricity, which was excited in the glass and the sealing-wax, are of a different kind, and we call that excited in the glass *positive* or *vitreous electricity*, and that in the sealing-wax, *negative* or *resinous electricity*. Indeed, the electricity

of all resins is (like sealing-wax) negative, when excited by friction; and this phenomenon was first remarked in *Amber*, which belongs also to these resinous substances and the whole series of phenomena is called electricity from the Grecian name for amber (Elektron).

If we bring the two balls together, the one which had been touched by the glass and the other by the sealing-wax, they will attract each other equally, as they are laden with electricity of a similar kind; but at the moment of collision, they fall away from one another, and prove themselves as non-electric. The two opposite states of electricity have united themselves and the balls contain again both electricities in equal quantities und are therefore *non-electric.*

We will now rub against each other a piece of glass and a piece of ribbon which is tightly stretched out, and then touch the two balls, which have become non-electric, the one with the piece of glass, the other with the piece of ribbon. Both appear again electric, and indeed, the ball touched by the glass will be repelled, while, on the other hand, it will be attracted by the ribbon. The case is just the contrary with the other ball. We then see, that both the bodies, which have been rubbed against one another, have become electrical, but that both receive an opposite state of electricity. This proposition is always valid, when two bodies are rubbed together, and we learn from it, that *no electricity can be excited by friction, but that only an ulterior distribution of both the electric fluids takes place, so that in the one a surplus of positive electricity is accumulated, and in the other of negative.*

If we rub a rod of metal, which we hold in the hand, with wool, we cannot prove, that there exists the slightest

trace of electricity in it. If we, however, fasten the rod to a handle of glass or sealing-wax, or if we wrap the part of which we take hold in silk, and then rub it, it will become strongly electrical, and we can observe all the same phenomena which we learned from the piece of glass or the sealing-wax.

As soon as we touch any part of it with the hand, then all electricity immediately vanishes from it. If we continue to rub a piece of sealing-wax or a glass rod at one end, and then test another part, which has not been rubbed, with the ball of pith, we shall find them quite non-electric. On the contrary, if we rub a metallic rod which is fixed to a handle of glass, in a certain place, and then test it in any other part we may choose, it will show itself as electrical. The two bodies, glass and metal, manifest themselves quite differently with regard to their relation towards electrical fluids.

In metals, the electricity excited in one part, conveys itself easily to another, and spreads itself over the whole body; in glass, the transition of the electricity finds a resistance; therefore, the spreading of it takes place very slowly, or not at all. Metal is therefore called a *conductor* of electricity; on the contrary, glass, sealing-wax etc. are *non-conductors* or *insulators*. The human body is also a *conductor*. A rod of metal rubbed with the hand, immediately sends the whole of its electricity into the ground; if, on the contrary, the rod is fastened to a non-conductor, the electricity finds a boundary, over which it cannot pass, and it remains in the metal; therefore the metal, with which the experiment is made, must be fastened to a piece of glass or sealing-wax, or hung up by a silken cord, that is, to use the technical term, *insulated*. Air is naturally a non-conductor, or else, through it all electricity

would immediately escape; but that is only, when it is dry, as in damp air all bodies quickly lose all their electricity. This is the reason, why in auditories, where so much humidity is mixed with the air, in consequence of the number of human beings collected together, and the quantity of burning lights, it is so difficult to make electrical experiments.

The electrical particles repel each other, through the swiftness of their motion within the conducting substances, till they arrive at the surface, where they can proceed no further, in consequence of the air, which is a non-conductor. Therefore all the electricity immanent in the conductor, collects itself on the surface, and forms there a thin layer. The greater the quantity of electricity accumulated in a body, the thicker is the layer, and the stronger the power, with which the repulsed particles strive to reach the exterior. This is called *electric tension.* Is the tension very great, the electricity escapes, in spite of the resistance of the surrounding air. Therefore every body can only be charged with electricity to a certain extent, which must depend on the nature of the body, and that by which it is surrounded.

If for example, a body charged with positive electricity approaches another insulated conductor, then the free electricity of the former attracts the opposite state of electricity in the latter and repulses that which is of a similar kind to its own. The ingredients of the neutral electricity of the second body will, therefore, be decomposed through the influence of the electricity of the first body, the positive electricity accumulates in the end which is averted from the first body, and the negative in that, which is turned towards it. If we remove the bodies from one another, then the decomposed electricities of the second body unite again, and the body be-

comes non-electric. If we touch the second body with the finger during the time it is under the influence of the first, then the positive electricity escapes into the ground, the negative, on the contrary, which is bound (or as it is technically expressed "latent") by the first body, cannot escape. If we break off the connection with the ground, and remove both bodies from one another, than the second, through the influence of the first, is charged with electricity, without the first having lost the least of its own. This is called *electromotion* through *decomposition.*

From the above described process, the second body receives continually the opposite kind of electricity to the first one. Both kinds can, however, be kept apart. We will take three bodies, A, B, C, of which A is charged with positive electricity, B and C are non-electric. We will place all three in a row, but so that B and C touch each other, while A stands at a short distance from B. Through the positive electricity of A, the negative electricity which is in the other two bodies, will now be decomposed. The negative electricity is attracted and accumulates in B, on the other hand, the positive is repelled and collects in C. If we now remove B and C a little from one another, then the decomposed electricities cannot unite again, and B and C are charged through decomposition. But as soon as we bring them both together, if it be but for a moment, the electricities unite and they are both once more non-electric.

From the decomposing power of electricity results a large number of phenomena, and many apparatuses are constructed to exemplify them, of which we will mention some of the most important. First we must remark, that the attraction of non-electric bodies through electricity can only be produced

by decomposition. We have observed, by the first experiment, that the sealing-wax, which has been made electric through friction, attracts the non-electric little ball of elder-pith, but as soon as they come in contact with one another, the ball is repulsed. The negative electric sealing-wax decomposes the natural electricities of the ball, and attracts the positive and repels the negative. As now the positive electricity of the ball is nearer the sealing-wax than the negative, the attraction of the former preponderates over the repulsion of the latter, and the ball is drawn towards the sealing-wax. As soon as they touch each other, the positive electricity of the little ball unites itself with an equal part of the negative electricity of the sealing-wax, the ball now retains a surplus of negative electricity, and is repulsed by the sealing-wax.

From similar proceedings originates also the accumulation of larger quantities of electric fluid by means of *electrical machines.* A circular plate or cylinder of glass is turned between two leather cushions which have been smeared with Amalgam (that is: a compound of mercury or quicksilver with another metal), and thereby rendered positive electric, while the rubbers become negative electric. The negative electricity of the rubbers is conducted into the ground. The part of the glass plate or cylinder, which has become positive arrives through rotation at a place, where it stands opposite or very near to a large insulated metallic ball furnished with spikes, which is called the *prime conductor.* Through the decomposing influence of the glass plate, the negative electricity of the conductor accumulates in the spikes and attains to such a tension, that it overcomes the resistance of the thin stratum of air, and unites itself with the positive electricity of the glass plate.

Is the tension of the electricity on the conductor so great, that it can no longer be held back by the resistance of the air, then, of course, the conductor cannot absorb any more electricity, however much may be conveyed to it. If we, however, place the conductor opposite to another, which is connected with the earth, then the positive electricity of the first conductor attracts the negative electricity of the second, and repels the positive, which escapes towards the ground. The two opposite electricities in the two conductors so attract each other, that their tension towards the surface is essentially impaired, and just on that account we can convey much more electricity to the first conductor, than it would be possible to do in any other case. This reciprocal union of the two electricities — as it is called by natural philosophers — occurs in its fullest perfection, when the conductors take the form of large smooth surfaces, which stand very near and parallel to one another. But to prevent the union of the electricities, which attract one another, a good insulator is placed between them, for instance: a glass plate. Thus an apparatus is formed which is called after its inventor "Franklin's plate"; a sheet of glass which is covered on both sides with a thin coating of tin-foil. If the two surfaces are curved, then we have a Kleist's or Leyden Phial or Jar, a glass phial or jar coated inside and outside with tin-foil. A metallic rod, having a knob at the top, is fixed into the mouth of the jar, and is made to communicate with the inside coating, while the outside is placed in communication with the ground. If we establish a communication between the inside and outside coating of such a jar by means of a conductor, the opposite electricities re-unite themselves, and the jar is discharged. A current of electricity flows through the conductor. If we insert

a human body in the circuit of the conductor, there follows a contraction of the muscles, which have been struck by the fluid and an excitement of the nerves, which is felt as an electric shock. If we break a part of the electric wire, then the two electricities can unite with one another through the air. This union takes place in the form of light and sound. In the part, which is interrupted, pieces of pasteboard, wood, glass etc etc., which have been inserted therein, will be pierced through or shattered to pieces; combustible bodies will be set on fire, in short, we can observe in a small way the whole of the phenomenon of lightning. Indeed, lightning is nothing more than a discharge of electricity from a cloud positively charged, to the surface of the earth, which is negatively charged; or from two clouds which are charged with opposite states of electricity. The effect of the lightning conductor is, that the electricity, which is attracted through decomposition towards the point of the lightning conductor, already unites itself by a slight tension with the opposite electricity in the cloud, and thus wards off the vehement discharge.

Mr. Holz, a private gentleman living in Berlin, has made an interesting application of the decomposing effect of electricity in the machine which has taken his name, viz: "Holz's machine", with the assistance of which very violent electric shocks can be produced. A pane of glass is provided with several indentations, in which are fixed pointed spikes from so-called vegetable parchement. When a small quantity of electricity is imparted to it by touching it with a glass rod or something of the same kind, which has been excited by friction, and then a second plate of glass which stands very near the first plate, be quickly turned, the electricity in the

second plate will be decomposed, the positive and negative accumulate in different parts of the glass plate, from whence they are taken up by imbibers and conducted to the inside and outside coating of a Leyden-jar, through the discharge of which we can obtain all the before mentioned effects in the most violent manner.

Friction is not the only means by which the natural electricity of bodies can be decomposed, contact alone can operate in the same manner. It is particularly the contact of metals and fluids, which produces a decomposition of electricities. If we immerse two different metals, for example, a plate of zinc and one of copper into a glass, which is filled with diluted sulphuric acid, the positive electricity goes from the zinc through the sulphuric acid to the copper, the negative from the copper through the sulphuric acid to the zinc. Free positive electricity collects in the protuberating end of the copper, and free negative electricity accumulates in the projecting end of the zinc. Such an apparatus as this is called a *galvanic element* or a *galvanic chain* according to the Italian anatomist *Galvani*, whom we have to thank for the first knowledge of this fact, although the most correct explanation was not given by him, but by his renownd countryman *Alessandro Volta.*

The prominent metallic ends of the chain are called its poles, and indeed the copper end is designated the positive pole or positive electrode, and the zinc end the negative pole or the negative electrode. If we join the poles by a wire, the opposite electricities are united. But, as the cause of the decomposition of the natural electricities continues in operation, viz: the contact of the two metals with the fluid; the

positive electricity flows continually from the copper through the wire to the zinc and from the zinc through the fluid to the copper, and inversely, the negative electricity flows continually from the zinc through the wire to the copper, and from the copper through the fluid to the zinc. This rotation of the two electricities in an opposite direction, is called an *electrical current*, and indeed, a *permanent current*, to distinguish it from the currents in the Leyden-jar, in which the electricities, which have accumulated on the inside and outside of the jar, discharge themselves with a shock. In order to know, in which direction the electricities move, it is necessary to observe, what metal forms the positive pole. In one apparatus it is copper; from this proceeds positive electricity, and as necessarily the negative electricity moves in the opposite direction, we say, the electric current flows from the copper through the wire to the zinc and from the zinc through the fluid to the copper.

The quantity of electricity, which is set in motion by such a contrivance, is very small; but it can be increased, if several elements be so united together, that the copper end of the one be always joined to the zinc end of the other. This is then called a *combined chain*, compounded from several elements. In the first element there remains a zinc end free, and in the last a copper end, which form the poles of the connected chain. If we join those by a conducting wire, then the whole of the electricities, which have been free, move through it, whereby we obtain very strong electric shocks.

If we then divide the conducting wire, which unites the poles, into two parts, the current is interrupted, as soon as those parts are separated by a non-conducting body. By inserting different bodies between the wires, we can conduct

the current through the same and study its effect. We will now submit a part of these effects to a more minute investigation.

As you will already know, there is in Nature a body which possesses the property of attracting iron; it is called *magnetite* or *magnetic iron ore.* When steel is rubbed with this magnetic iron, it imbibes the same quality and can then transfer it to other steel. If we have such a magnet of steel in the form of a needle which is so placed on a point, that it can easily be turned round, we observe, that the needle continually takes a certain direction, whereby the one end turns towards the North, the other towards the South. If we now pass the current of the galvanic chain over the needle, we remark, that the needle leaves its usual place and turns its North point either towards the East or the West, until it comes to rest in a fixed position. If we interrupt the current, the needle returns again to its natural situation.

Such a needle can assist us to discern whether an electric current be present; but if the current be very weak, then the deviation of the needle is very slight and scarcely perceptible.. It can be made stronger, if we let the wire which conducts the current, pass several times round the needle, by winding the wire on a frame, in the middle of which the needle can easily turn. That the current may not go diagonally from one coil to another, but really flow through every coil one after the other, it is necessary to enclose the wire in an insulated covering. This is effected by spinning silk over the wire. In this case, the effect of the current on the needle is greatly multiplied; therefore, such an instrument is called a *multiplicator.* For greater convenience we can also bring a hand on the needle, which plays on the outside of

the frame over a partition, and thus points out the position of the magnetic needle which is in the interior.

If we unite such a multiplicator with the chain, and then so change the connection, that the current flows in an opposite direction, then we observe, that the needle also in both cases takes another direction. If we observe this direction once for all, then the instrument can not only be used as the advertiser of a current, but it shows us, at the same time, its duration, and from the degree of deviation we can judge of the strength of the current.

In the different experiments which I have described, the closing of the chain was purely metallic.— It only consisted of the multiplicator-wire and the pole-wire, which led to it. Now we will unite the latter with two metallic tin plates and place these parallel to one another in a glass of water. As water is a very bad conductor of electricity, we will add a little sulphuric acid to it, through which its power of conduction is immensely improved. The current goes from one plate through the water to the other. We immediately see a quantity of little bubbles of gas collect on both plates, which rise to the surface and then are lost. We think we remark, that the number of bubbles on both plates are not the same; on the plate which is connected with the positive pole, there appear fewer than on the other.

To observe this more exactly, we cover each plate with a funnel filled with water, and catch the developed gas. We obtain in each funnel a colourless gas, but that which is developed on the positive plate, only occupies half the space as the other. We will examine the gas of the positive pole more minutely; it has neither smell, taste, nor colour; if we bring a lighted shaving to it, it takes fire and burns with a bright

flame. Through these properties we can recognize it as that gas which chemists call *Oxygen*, and which forms one of the ingredients of water. Now we will test the other gas. It is also without smell, taste and colour; when a glowing shaving is brought near it, it takes fire and burns with a feeble blue flame. Those are the properties, which belong to *Hydrogen*, the other ingredient of water. As chemistry teaches us, that one part of oxygen and two of hydrogen are united in water, we now perceive, that through the passage of the electric current the chemical union of water in its ingredients is decomposed and that these ingredients appear in their original form as aëriform or gaseous bodies. This decomposition is called *electro-chemical* or *electrolysis.*

The two gases which we have obtained from the water through electrolysis, can be again combined to water. If we, for example, do not catch them separately but together, by bringing the two pole-plates into a closely corked vessel, and conducting through the cork a curved glass tube under a glas filled with and turned down in quicksilver, we obtain in the glass a quantity of both sorts of gas in the same state in which they were in the water. If we now raise the glass with the closed mouth and bring a flame to the opening, we hear a violent explosion, and the side of the glass, which was before quite dry, is now covered with drops of water, which have been produced from the union of the two gases. In consequence of the property of this mixture of gas it has acquired the name of *inflammable gas.*

Other combined fluids, which conduct the electric current, are also decomposed by means of this gas, and many of these decompositions have obtained a great practical importance. If we dissolve a metallic salt in water, for example, sulphate of

copper, which is a combination of copper, oxygen and sulphuric acid, we obtain a blue liquid, which is so decomposed through the current, that metallic copper secretes at the negative pole, while oxygen and sulphuric acid show themselves at the positive pole. The copper encrusts thereby the negative pole with a layer which perfectly represents it in all its protuberances and cavities, and which can be taken off after it has attained a certain opacity. We then have an inverted impression of the plate at the pole, on which every protuberance is represented by an elevation and cavities by indentations. This is used to multiply medals and such things; an impression of the object to be multiplied is taken in wax, gutta percha and such like, and then furnished with a conducting cover, which in connection with the negative pole is exposed to the influence of the electric current. The first impression gives an inverted copy of the original object, a so-called *matrix*; the galvanic impression is, however, a true imitation of the same.

Corporeal objects, as busts, statues etc. can be copied in this manner, which is called *electro-metallurgy*, or the *galvanic plastic art*; a form is made over the body, consisting of single pieces which are then set together, and a solution of sulphate of copper is poured into the cavities, and then through the current the copper is precipitated on to the form.

A second important application of electro-metallurgy is made in *chalcography* or the *art of engraving on copper*. A great number of impressions cannot be taken from the copper-plates which are engraved by artists, in consequence of the pliability of their material, as the delicate lines suffer through the pressure of the printing press. That is the reason, that the first impressions, the so-called "épreuves d'artiste" and

"avant la lettre" are so much in request. But now the plates which have been engraved by the artist can be several times galvanically imitated, and a great number of impressions taken from them, while the original plate remains quite uninjured, whereby naturally the number of the good impressions is increased, and their price becomes much more reasonable. In the same manner we deal with forms cut in wood for *wood-engravings*, or other purposes, in short, with all objects which are used in great numbers, in the same form, for example, government seals, forms to press decorations in leather etc.

Another phase of electro-metallurgy consists in furnishing objects with a metallic coating in a galvanic manner. Thus we can *electro-plate* all objects by connecting them with the chain of the negative pole, and putting them into a solution of muriate of gold, silver, or sulphate of iron, and then exposing them to the influence of the electric current. Galvanic steeling is sometimes undertaken with copper-plates, to give them a greater hardness, and thereby greater power to resist the pressure of the printing-press. A very thin precipitation of a metal, which changes into different colours through the reflection of the light, is used to decorate bells for the table and other metallic objects.

If we conduct the current of the chain through the above described vessel, in which the water is decomposed through two metal plates, while the developed inflammable gas is transported through a covered glass-tube into a bell, we can measure the quantity of inflammable gas, which is developed in a given time. If we put at the same time the multiplicator in the circuit of the chain, we shall find, that the quantity of inflammable gas, which is developed, is so much larger or smaller, according to the deviation of the magnetic needle.

We eonelude from this, that the deeomposing effeet of the current is mueh more eonsiderable, the more electricity is set in motion through the ehain, or the stronger the eurrent. If we observe it for a longer time, we find, that the effeet is not equal. Immediately after the closing of the chain, the decomposition of the water as well as the deviation of the needle of the multiplieator is very strong, gradually however, both become weaker and weaker, and they are at last quite unobservable. What is the eause of this diminution in the action of the chain? It ean lie in the ehain itself or in the deeomposing apparatus.

The plates of the deeomposing apparatus or the *Voltameter*, as sueh an instrument is ealled, by natural philosophers, are formed of the same metal, Platina; they are therefore *homogeneous* and do not require in the diluted sulphuric aeid any different electrieal tension, and if we unite them with the multiplieator, the magnetie needle does not deviate in the least. If we, however, let the eurrent of the ehain, run through the voltameter, and then unite it with the multiplicator, we obtain a strong deviation of the magnetic needle, the Voltameter now develops also a eurrent and indeed, this current takes an opposite direetion in the Voltameter, to that whieh the eurrent in the chain took originally. These homogenial platina plates of the Voltameter have beeome through the flowing of the eurrent through the ehain, the poles of a ehain, and give out a eurrent which is called the *secondary* or *polarization current.* As this current takes the opposite direetion to that of the original current of the chain, it is clear, that it must weaken it. The eause of this polarization eurrent is, however, no other than the developed gas. The oxygen namely, which is secreted in the positive plate, makes it

negative, and the hydrogen, which is secreted in the negative plate, makes that positive; a platina plate coated with oxygen and one with hydrogen, are no longer homogeneous, but stand in relation to one another like zinc and copper, they have different electrical tension and form together a chain.

That which takes place in the Voltameter, must also partly take place in the chain. In that, the current goes, as we have already seen, from the zinc through the diluted sulphuric acid to the copper. It there decomposes the water, the oxygen is parted from the zinc and the hydrogen from the copper. Now the oxygen is innoxious; as it has a great anology to zinc, it forms in connexion with it a chemical combination which is called oxyde of zinc, and this again combines itself with the sulphuric acid to sulphuric oxyde of zinc, or sulphate of zinc, which is dissoluble in water. The oxygen, which is separated from the copper, occasions by its strong positiveness a current from the copper to the zinc, which acts contrary to and weakens the original current. Thus the chain contains in itself the cause of the diminution of its strength.

There are, however, means to obviate this cause. *Daniell*, an English Natural Philosopher, has specified a remedy, which simply consists in removing the hydrogen, in the same proportion as it rises. This is to be done, by surrounding the copper with a fluid, which has a great chemical relation to hydrogen. Such a fluid is a solution of sulphate of copper. The hydrogen, as soon as it is formed, absorbs the oxygen from the sulphate of copper and forms it into water, the copper is parted from it and covers the plate at the pole with an equal layer, as we have seen by the electro-metallurgy. Thus the whole of the hydrogen is removed, and the copper

plate constantly retains a fresh surface. To avoid the sulphate of copper from touching the zinc, through which it would be directly decomposed, the space which contains the zinc, is separated from that which holds the copper, by a porous partition of burnt clay, or a similar substance, and the space for the zinc is filled with diluted sulphuric acid. The partition hinders the mixture of the two fluids, while it permits the movement of the electricity through its pores.

In this manner we have a *permanent chain*, the power of which can exist for days together, but as the dilution of the sulphate of copper continually decomposes, we must, from time to time, renew it; and as the sulphuric acid changes gradually into sulphate of zinc, that must also be renewed. The zinc will gradually be quite dissolved, and we learn from that, that we cannot produce the movements of electricity from nothing, but only at the expense of the consumed zinc. *From nothing comes nothing.*

Besides this Daniell's chain, there are many other *permanent chains*, of which we will only name a few. In Grove's chain, platina takes the place of copper, and stands in smoking nitric acid (aqua fortis). Nitric acid forms likewise with hydrogen, water, because it gives it a part of its oxygen, and retains its nitric acid. The tension between zinc and platina is much greater, than that between zinc and copper, the chain is therefore stronger: but the consumption of sulphuric acid is very expensive, and the vapours which it exhales, are very deleterious to metallic objects and to the lungs. As platina is very dear, Bunsen has replaced it by a coal especially prepared for that purpose, which works in the same manner as platina. For technical purposes as well as for electro-metallurgy and telegraphy Daniell's chains are most to be recom-

mended, particularly in the somewhat altered form, which Siemens and Halske have given them.

From the two effects of the electrical current, which we have already observed, the one, the electrolysis, takes place in the interior of the body which conducts the current; the other, the deviating effect of the magnetic needle, is carried out by the current through the air in the distance. Besides these differant actions the current possesses many more, which we cannot singly discuss. Thus it heats, for example, all conductors through which it flows, and this heating can increase to glowing, so that we can, with the assistance of a fitting conductor, make a wire, at a great distance from the chain, red hot.

This is used to spring mines, and in surgery to disperse swellings without the loss of blood. If we conduct the current of a strong chain through two ends of coal, which touch each other, and then separate them a little from one another, small particles of glowing coal will be drawn from one end over to the other, and we obtain a brilliant *electrical light*, which is now very much used for illuminations. The most important effect of the current is, in every case, the *magnetizing*, of which we will speak more at large, as the whole of telegraphy is founded upon it.

If we wind a quantity of wire round a rod of soft iron and conduct through it an electric current, the iron becomes magnetic and retains this capacity as long as the current lasts; it is, however, immediately non-magnetic, as soon as the current is interrupted. In this manner it is possible for us to procure a magnet or load-stone, and then again to transform it into an ineffective piece of iron according to our own plea-

sure. Such magnets are called *electro-magnets*. They can, if the current be strong enough, attain to very great power, so that we can hang some hundred weight of iron on them, which they can carry, but it falls away from it, as soon as the current is interrupted. By this means, it is possible to produce electrical motions in a distant place. For instance, if we place a chain in Berlin and conduct the wires as far as Cologne to an electro-magnet, the magnet in Cologne will attain its magnetism and lose it again, as soon as we open and shut the chain in Berlin. A piece of iron brought in Cologne near the electro-magnet, a so-called *anchor*, which is kept in equilibrium by a spring, will be attracted to it as soon as the current is closed in Berlin, and is again detached if the current be opened. We can use these motions to give signs.

We can also set machines in motion with the help of electro-magnetism. If, for example, we bind a hook to the anchor (as it is fixed to the pendulum of clocks which are placed against the wall), which interlocking in the spokes of a wheel, set it turning, we can set the hand of a clock in regular rotation, if the closing and opening takes place regularly. This last can be effected by the pendulum of a clock, but then the electro-magnetically moved hand must keep continually the same pace as the closing and opening of the clock. As, however, we can insert many such electro-magnets with clock work in the same conduction, we can also, by means of one clock, keep many others, in the most different places, in the strictest unity with one another.

It has also been tried to employ electro-magnetism to raise burdens, but the machines which are necessary for the purpose, are much too expensive to be brought into practice.

In cases where less power is necessary, the electro-magnetic machine can be used. The most important, because it is much required in science, is the little machine, which the optician Wagner in Frankfurt on the Maine has invented, and to whom the German Confederation promised one hundred thousand guldens, if he could construct an electro-magnetic engine. He was not able to construct the engine, but the little apparatus which he invented on this occasion, has made his name immortal. It is called after him Wagner's Hammer.

A little electro-magnet stands perpendicularly, and above it swings an iron anchor which is fastened to a lever. The lever is pressed by means of a spring against a platina spike and the current of the chain is so arranged, that it goes from the lever to the platina spike, from thence to the coils of the electro-magnet, and then back again to the chain. Through that the magnetism ceases, the anchor is no longer attracted, and the spring again presses the lever against the spike. Now, if the current be again closed, the anchor will be again attracted and the current interrupted, and thus the apparatus continues in play, as long as the chain has a current to develop.

Dr. Siemens has made a very ingenious application of this apparatus, in *telegraphy.* It is, however, especially applied medically, to *stimulate* the *muscles* and *nerves.* The stimulus takes place at the moment, in which the current is closed and interrupted. It is, like the closing and opening, only of short duration. If the stimulus should last longer, then the closing and opening of the current, must be successively repeated, which can best be effected by *Wagner's Hammer.* It is, however, much more expedient to use for the purpose of stimulation, such currents which only last for a

short time, so that the opening follows almost immediately on the closing. If we have two coils of wire, of which the one is united to the chain, and therefore a permanent current flows through it, while the other is united to the multiplicator, no part of the current from the chain can go through the second roll, and the needle of the multiplicator therefore does not deviate. As soon as the current in the first coil is interrupted and then again closed, we see a sudden motion in the needle of the multiplicator. As both coils stand near each other, the first coil influences the second, and indeed in such a manner, that every time the current rises in the first coil, another is excited in the second, which takes an opposite direction; but when the current in the first coil disappears, then a current rises in the second coil, which flows in the same direction. The currents which show themselves in the second coil, are called *induced magnetism* or *magnetic induction.* They only last as long as the act of closing and opening in the first coil. In consequence of this short duration they are especially suited to stimulate the muscles and nerves. Indeed, if we let an induced current go through a muscle, we can see, each time, that the current in the first coil is closed or interrupted, that a sudden contraction, a so-called convulsive motion of the muscles takes place. But if we insert one of Wagner's hammers in the circuit of the chain near the first coil, so that the current is continually closed and interrupted, the single induced currents follow each other very quickly, and the muscle falls into a continual convulsive state.

Induced currents can also be produced by the magnet. If we bring a magnet quickly near a coil, a momentary current is produced in one direction; but when we remove the

magnet, then a current is formed in an opposite direction. Naturally, the same occurs, when the magnet is at rest, and the coil in motion. This is most efficiently acquired, when two coils are set in quick rotation before the end of a magnet in the form of a horse-shoe. As the coils alternately approach and retreat from the end of the magnet, a quantity of compressed induced currents are produced, which are conveyed outwardly by trailing springs.

The effect is essentially increased, if we put in the coils a piece of soft iron curved like a horse-shoe, which must be set in motion with the coils. Through the approach of the soft iron towards the magnet and its retreat from it, it becomes alternately magnetic and non-magnetic, and through this appearing and disappearing of magnetism, induced currents are also produced in the coils. In this manner the *magneto - electric rotation machine* is formed, which is used for medical purposes, and which we often see at fairs, where everybody for a small sum can have the pleasure of trying the wonderful effects of electricity on his own person.

The effect of induction through the rise and disappearance of magnetism, can be united with the first kind of induction through the closing and opening of a permanent current. If we, for example, put a piece of soft iron in the first coil, it will become magnetic, if the current be closed, and the magnetism ceases as soon as the current is opened. In this manner, the induced current in the second coil is greatly strengthened. Apparatuses of this kind are principally used medicinally. Through the facility, with which it stimulates the nerves and muscles, medical science has not only obtained an important remedy for curing the diseases of these organs,

but also the scientific investigation of the actuality of their structure has made great progress.

The inducted currents are very similar to those obtained by electric friction. Like those, they also give a shock with light and noise, when the circle is interrupted in any part. Lately, apparatuses of this kind have been constructed, which eject sparks twelve inches long, and sometimes longer. The inducted sparks are excellently adapted to set mines on fire.

The phenomena which I have here concisely described, do not in the least exhaust the large sphere of electricity, but are sufficient to show how the human spirit of enquiry, on the path of calm examination, is capable of accomplishing something very great. The researches of which I have endeavoured to give you a concise view, began at the end of the last century, but the greater part of them have been made during the last thirty years. And besides that devastating mighty power which demonstrates itself in a thunder storm, has been forced into the service of man, and he has made it as the bearer of thoughts, the medium of intercourse between the most distant parts of the earth, so that that which formerly only served to lay houses in ashes, now, instead of fire, melts metals in prescribed forms; and that which only distroyed human beings, is now used as a remedy to eradicate diseases. Who can say, what further progress the future can bring us? We can be justly proud of our century, which is decried by many as so material, and still in which the human mind has celebrated not the least of its triumphs.

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